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THIS DOCUMENT CONTAINS:
1) A GENERAL OVERVIEW OF THE CONTAMINATION PROCESS-GEOLOGICAL AND HYDROLOGICAL. 2) A BRIEF DESCRIPTION OF THE "DYNAMIC CLUSTER" SAMPLING TECHNIQUE DEVELOPED FOR THE COMPREHENSIVE SURVEY AT RMA. 3) SUMMARY OF THE SAMPLING PROGRAM WHICH IS GROUPED INTO 3 CATEGORIES - 3600 MONITORING PROGRAM, GEOPHYSICAL SAMPLING, AND THE PROJECTED COMPREHENSIVE SAMPLING PROGRAM.

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CONTAMINATION DIFFUSION AND ENVIRONMENTAL SAMPLING -- AN OVERVIEW

AUG 76

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Commerce City, Colorado

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THE TRANSPORTING MEDIUM FOR PARTICULATE CONTAMINANTS IS EITHER WIND OR SURFACE WATER MOVEMENT. THE CONTAMINANTS, THEREFORE, CONCENTRATE IN AREAS CONTROLLED BY THESE TRANSPORTING MEDIA -- ON OR CLOSE TO THE GROUND SURFACE. THE TRANSPORTING MEDIA FOR LIQUID CONTAMINANT, ON THE OTHER HAND, IS EITHER SURFACE RUN-OFF, SUBSURFACE RUN-OFF, OR GROUNDWATER RUN-OFF. THESE CONTAMINANTS, THEREFORE, TEND TO CONCENTRATE MUCH DEEPER IN THE UNCONSOLIDATED MANTLE.

CERTAIN COMPOUNDS TEND TO GROUP TOGETHER INTO COMPOUND ASSOCIATIONS IN A SPECIFIC ENVIRONMENT DUE TO SIMILAR MIGRATION CAPACITIES (RELATIVE MOBILITIES). THE TENDENCY FOR COMPOUNDS TO GROUP TOGETHER SIMPLIFIES THE MAPPING TASK IN THAT BY TESTING FOR EITHER INDICATOR OR PATHFINDER ELEMENTS, IT IS POSSIBLE TO TRACE THE SPATIAL BEHAVIOR OF THE POLLUTANTS.

CONTAMINANT DISPERSION ALSO OCCURS THROUGH SOIL EROSION. SEVERAL CONTAMINATED AREAS EXIST ON RMA WHICH ARE SOURCES OF GROUND SURFACE POLLUTION BY SOIL MOVEMENT. THIS CAN BE SIGNIFICANT IN AN ARID ENVIRONMENT IN AREAS WHICH ARE NOT PROTECTED BY A VEGETATIVE COVER (EXAMPLE BASIN A AND PARTS OF THE ARSENAL DURING THE WINTER MONTHS WHEN

VEGETATION IS DORMANT). THE ANNUAL SOIL LOSSES FROM SHEET AND RILL EROSION BY RAINFALL CAN BE DETERMINED BY THE UNIVERSAL SOIL LOSS EQUATION. THIS TECHNIQUE CAN PROVIDE A MEASURE OF THE VOLUME OF CONTAMINATED SEDIMENT MOVED OR DELIVERED TO A STREAM.

VIEW GRAPH 1

A VERTICAL SECTION THROUGH THE UNCONSOLIDATED MANTLE REVEALS A SERIES OF DISTINCT LAYERS OR ZONES WHICH DIFFER IN THEIR CHEMICAL, PHYSICAL, AND MECHANICAL PROPERTIES. THE UPPERMOST A HORIZON VARIES FROM A FEW INCHES TO ONE FOOT IN THICKNESS AND REPRESENTS AREAS OF BIOACCUMULATION. MATERIALS REMOVED BY RAIN WATER FROM THE A HORIZON ARE CARRIED DOWNWARD IN SOLUTION AND ARE DEPOSITED IN THE B HORIZON. IMPERVIOUS HARDPAN AND CLAYPAN LAYERS MAY DEVELOP IN THE B HORIZON BY THE ACCUMULATION OF DOWNWARD MOVING MATERIAL WHICH INCLUDE IRON AND ALUMINUM MINERALS. IN ARID CLIMATES, CALCIUM CARBONATE, SODIUM SULPHATES, AND OTHER SALTS MAY ACCUMULATE JUST BELOW THE B HORIZON IN THE C LAYER. THE C LAYER MAY DISPLAY WEATHERING, INCLUDING OXIDATION, HYDRATION, AND LIME ACCUMULATIONS.

KNOWLEDGE OF THE SOIL PROFILES INCREASES THE PROBABILITY OF LOCATING THE CONTAMINATED AREAS AND ALSO PERMITS A

CONSTANT RELATIVE SAMPLING PROCEDURE TO BE MAINTAINED. ALL SAMPLES MUST BE TAKEN FROM THE SAME HORIZON FOR ALL SAMPLING LOCATIONS; OTHERWISE, THEY WILL NOT BE COMPARABLE. A UNIFORM SAMPLING PROCEDURE INCREASES THE PROBABILITY OF LOCATING THE CONTAMINATED ZONES.

ONE OF THE OBJECTIVES OF THE COMPREHENSIVE SURVEY IS TO APPRAISE THE "SPATIAL STRUCTURE" OF THE CONTAMINANTS WHICH REPRESENT THE LOCATION OF EACH ELEMENT RELATIVE TO EACH OF THE OTHERS AND THE "SPATIAL PROCESSES," WHICH ARE THE MECHANISMS WHICH PRODUCE THE SPATIAL STRUCTURE OF THE CONTAMINANT DISTRIBUTION.

AT RMA, CONTAMINANT EMPLACEMENT AND DIFFUSION WILL BE STUDIED FROM THE SYSTEMS VIEWPOINT. THAT IS THE DYNAMIC PROCESS WHICH WILL MONITOR CONTAMINANT MOVEMENT THROUGHOUT THE TOTAL ECOSYSTEM.

A DYNAMIC CLUSTER SAMPLING PROCEDURE WAS DEVELOPED TO BE USED IN THE COMPREHENSIVE SURVEY AT RMA.

AN ATTRACTIVE ATTRIBUTE OF DYNAMIC SAMPLING IS THAT AS INFORMATION IS GATHERED, IT IS USED TO DIRECT FURTHER SAMPLING WITHOUT BIASING THE PROBABILITY PROPERTIES OF THE SAMPLE.

DATA ON SOILS AND GROUNDWATER WILL BE GATHERED FROM DRILL SITES PATTERNED IN CLUSTERS OF 16 BORE HOLES PER CLUSTER, ARRANGED IN A 4 X 4 SQUARE GRID. FIELD DATA ON LAND SURFACE TOPOGRAPHY, PHYSICAL PROPERTIES OF SOILS, GROUNDWATER LEVELS, AND BEDROCK WILL BE LOGGED. SOIL SAMPLES WILL BE COLLECTED AT THE APPROPRIATE DEPTH; SENT TO THE SOILS LABORATORY WHERE IT WILL BE DIVIDED INTO TWO PARTS. ONE PART OF THE SAMPLE WILL GO TO THE MATERIAL ANALYSIS LAB DIVISION FOR CHEMICAL ANALYSIS OF VARIOUS CONTAMINANTS. THE OTHER PORTION WILL BE ANALYZED IN THE SOIL LABORATORY FOR SOIL MOISTURE, MECHANICAL, AND MINERAL PROPERTIES. WHILE THE ANALYSES ARE BEING PERFORMED, A SECOND CLUSTER OF 16 SITES WILL BE DRILLED AND SAMPLED. THE RESULTS FROM THE FIRST CLUSTER OF SAMPLES WILL BE MAPPED TO DETERMINE THE POSITIONING OF THE THIRD CLUSTER OF 16 SAMPLING SITES. THE CLUSTER WILL BE LOCATED IN THE DIRECTION OF THE MAXIMUM CONCENTRATION OF THE CONTAMINANT BEING MAPPED. THE ANALYZED RESULTS FROM THE SECOND CLUSTER WILL LIKEWISE BE USED TO DETERMINE THE POSITIONING OF THE FOURTH CLUSTER, ETC. THIS TECHNIQUE OF MAPPING EACH CONTAMINANT AND POSITIONING THE CLUSTER OF SAMPLES IN THE DIRECTION OF MAXIMUM CONCENTRATION WILL PERMIT TRACKING THE POLLUTION PLUME TO ITS ORIGIN WITH MINIMUM EXPLORATORY

DRILLING. PERIODICALLY, THE CLUSTER WILL BE COMBINED; AND ANALYSIS WILL BE PERFORMED ON THE TOTAL COMBINED SAMPLES. THIS WILL YIELD AN INCREASE IN THE SAMPLE SIZE AND AN INCREASED RELATIVE HOMOGENEITY OF THE ELEMENTS BEING SAMPLED. BY COMBINING THE CLUSTER INTO A TOTAL SAMPLE, ONE IN EFFECT, IS EVALUATING THE REGIONAL PATTERN OF THE POLLUTANTS AS COMPARED TO MORE LOCAL, LARGER-SCALE BEHAVIOR WITHIN EACH CLUSTER.

IT IS POSSIBLE THAT SEVERAL PLUMES WILL BE ENCOUNTERED, EACH ORIGINATING FROM A DIFFERENT SOURCE AND CONTAINING THEIR OWN UNIQUE GROUPING OF COMPOUNDS. WHEN THIS OCCURS, EACH PLUME WILL BE TRACED SEPARATELY TO LOCATE ALL SOURCES.

ON-GOING EXPLORATORY DRILLING ALONG THE NORTHERN BOUNDARY OF RMA HAS REVEALED THE EXISTENCE OF AT LEAST TWO CONTAMINATED GROUNDWATER PLUMES. ONE PLUME CONTAINS DIMP, Cl^-, AND Na COMPOUNDS. THE OTHER IS A DCPD AND PESTICIDE PLUME. BECAUSE OF THE HIGH PRIORITY PLACED UPON CONTAINMENT OF CONTAMINANT DISPERSION, THIS PART OF THE ARSENAL WOULD BE A LOGICAL PLACE TO START THE SAMPLING PROGRAM. AN ALTERNATE APPROACH WOULD BE TO BEGIN AT KNOWN CONTAMINANT HOT SPOTS.

VIEW GRAPH 2

VIEW GRAPH 3

A TEST SAMPLING GRID, SPACED 250 FEET APART, WILL BE CONSTRUCTED INITIALLY TO PRETEST THE SAMPLING METHOD AND DATA-HANDLING PROCEDURE. THE DISTANCE BETWEEN THE SAMPLING BORE HOLES WILL BE ADJUSTED AS MORE DATA BECOMES AVAILABLE ON THE DIFFUSION RATES OF CONTAMINANT CONCENTRATION WITH DISTANCE. THE MATHEMATICAL RELATIONSHIP BETWEEN CHANGE IN CONCENTRATION LEVEL PER UNIT CHANGE IN DISTANCE WILL BE CALCULATED FOR EACH CONTAMINANT, AND THE GRID SPACING WILL BE ADJUSTED TO THE OPTIMUM DISTANCE. PRELIMINARY TESTS SHOW THAT THE BEST FIT REGRESSION EQUATION, EQUATING THE CHANGE IN DIMP CONCENTRATION WITH DISTANCE MEASURED FROM THE CENTER OF THE DIMP PLUME IS $Y = A + B \log X$.

VIEW GRAPH 4

ONE-FOOT SECTIONS OF THE SAMPLING CORE WILL BE COLLECTED TO SERVE AS THE SAMPLES FOR BOTH MECHANICAL AND CHEMICAL ANALYSIS. SOIL SAMPLES WILL BE TAKEN AT SIX DEPTHS, SO AS TO INCREASE THE LIKELIHOOD OF INTERCEPTING THE ZONES OF CONTAMINANT CONCENTRATION. THESE ZONES ARE: (1) THE A SOIL HORIZON, WHICH IS THE ZONE OF CONTAMINANT BUILT THROUGH (A) BIOACCUMULATION IN THE SOIL ORGANIC MATTER; (B) UPWARD MIGRATION OF CONTAMINANTS BY CAPILLARY ACTION AND SURFACE EVAPORATION OF WATER; AND (C) ACCUMULATION OF POLLUTANTS ON THE GROUND SURFACE BY BOTH WIND OR

VIEW GRAPH 5

SURFACE WATER TRANSPORT; (2) THE B SOIL HORIZON WHICH IS THE ZONE OF ILLUVIATION OR ACCUMULATION OF COMPOUNDS LEACHED FROM THE UPPER HORIZONS; (3) A POINT MID-WAY IN THE ZONE OF AERATION REPRESENTING THE TRANSITION ZONE; (4) THE CAPILLARY FRINGE IMMEDIATELY ABOVE THE GROUND-WATER TABLE; (5) A POINT BELOW THE TOP OF THE WATER TABLE; AND (6) AT THE BEDROCK SURFACE. THE SOIL SAMPLES TAKEN IN THE ZONE OF SATURATION WILL PROVIDE A RATIO OF THE CON-TAMINATION LEVEL IN THE SOIL COMPARED WITH THAT MOVING IN THE GROUNDWATER. ADDITIONAL SAMPLES WILL BE TAKEN AT THE TOP OF CLAY LAYERS OR LENSES WHENEVER THEY ARE ENCOUNTERED, TO DETERMINE THE EFFECT OF CLAY AS A POINT OF CONTAMINANT CONCENTRATION. CLAY LAYERS IN THE REGOLITH MAY BEHAVE AS SELECTIVE, PHYSICAL, CHEMICAL, OR OSMOTIC FILTER AIDED BY THE GREATLY REDUCED RATE OF DOWNWARD PERCOLATION OF GROUND-WATER AND THE POSSIBLE PRESENCE OF CLAYS HAVING A HIGH IONIC EXCHANGE CAPACITY. GROUNDWATER WILL ALSO BE SAMPLED AT TWO DEPTHS, ONE AT THE WATER TABLE; THE OTHER AT THE BEDROCK SURFACE AT EACH DRILL SITE.

IN SEVERAL PLACES ON THE ARSENAL, THE B HORIZON DOES NOT OCCUR; AND THE SOILS GRADE DIRECTLY FROM THE A TO THE C HORIZONS. THIS USUALLY OCCURS IN YOUNGER, POORLY DEVELOPED

AZONAL SOILS. IN ORDER TO AVOID MISSING DATA FOR SITES WHERE HORIZONS ARE ABSENT, ALL SAMPLING WILL CONSISTENTLY BE TAKEN AT UNIFORM DEPTHS PREDETERMINED TO CONCIDE WITH THE SOIL PROFILE HORIZONS.

EACH OF THE CONTAMINANTS WILL BE MAPPED INDIVIDUALLY FOR EACH OF THE SIX HORIZONS SAMPLED, THUS PROVIDING A THREE-DIMENSIONAL VIEW OF THE CONTAMINANT DISTRIBUTION. THE MAXIMUM CONCENTRATION ENCOUNTERED AT EACH SITE WILL ALSO BE MAPPED TO SHOW A PLAIN VIEW OF THE HIGHEST LEVELS OCCURRING ON THE ARSENAL.

VIEW GRAPH 6

PRINCIPAL COMPONENT FACTOR ANALYSIS WILL BE PERFORMED ON THE DATA AND THE FACTOR SCORES MAPPED. PRINCIPAL COMPONENT FACTOR ANALYSIS WILL DETERMINE THE CORRELATIONS AND BEHAVIOR OF THE CONTAMINANTS AS GROUPS OR ASSOCIATIONS. THE INFORMATION WILL BE OBTAINED FROM THE FACTOR LOADINGS,

VIEW GRAPH 7

WHICH WILL IDENTIFY NEW GROUPINGS INDICATING THAT NEW POLLUTION PLUMES WERE ENCOUNTERED.

VIEW GRAPH 8

THE MAPS OF THE FACTOR SCORES FOR EACH OF THE FACTORS WILL PROVIDE INSIGHT ON THE SPATIAL DISTRIBUTION OF EACH OF THE CONTAMINANT GROUPS INDIVIDUALLY AND WILL SERVE TO IDENTIFY THE LOCATION AND

VIEW GRAPH 9

DIRECTION OF THE PLUME, THUS INDICATING WHERE THE NEXT

SAMPLING CLUSTER IS TO BE POSITIONED. FACTOR ANALYSIS OF THE TOTAL SET OF VARIABLES WILL, THROUGH THE CORRELATION COEFFICIENT, PROVIDE THE LINKAGE WEB BETWEEN THE CONTAMINANTS AND THE PHYSICAL ECOSYSTEMS.

VIEW GRAPH 10

THE RELATIONSHIPS AND THE LINKAGES WILL BE MAPPABLE THROUGH THE FACTOR SCORES. MULTIVARIATE DISCRIMINATE ANALYSIS, USING THE FACTOR SCORES AS SURROGATE WEIGHTS, WILL SERVE AS A COMPARISON OF SIMILARITY AND DIFFERENCES BETWEEN DIFFERENT REGIONS REPRESENTING EITHER DIFFERENT CONTAMINATED AREAS OR DIFFERENT SOURCE AREAS. THE MULTIVARIATE DISCRIMINANT FUNCTION CAN ALSO SERVE AS A MODEL FOR SIMULATION.

VIEW GRAPH 11

THE SAMPLING PROGRAM AT RMA CAN BE GROUPED INTO THREE CATEGORIES: (1) THE ON-GOING 360° SURFACE AND GROUNDWATER MONITORING PROGRAM; (2) THE GEOPHYSICAL SAMPLING IN SUPPORT OF GEOHYROLOGICAL CHARACTERIZATION; AND (3) THE PROJECTED COMPREHENSIVE SAMPLING PROGRAM.

VIEW GRAPH 12

VIEW GRAPH 13

THE 360° WATER SAMPLING PROGRAM CONSISTS OF MONITORING FOR CHEMICAL CONTAMINATION ON EITHER A MONTHLY OR QUARTERLY BASIS 93 GROUNDWATER WELLS, 8 SURFACE WATER COLLECTION POINTS

ON THE ARSENAL; ALSO 21 GROUNDWATER WELLS AND 11 SURFACE WATER MONITORING SITES OFF ARSENAL. THERE ARE ALSO 71 ADDITIONAL WELLS BEING MONITORED FOR WATER TABLE LEVELS. THIS PROGRAM HAS BEEN COORDINATED WITH INPUTS FROM THE SHELL CHEMICAL COMPANY, THE COLORADO DEPARTMENT OF HEALTH, AND RMA.

THE WATER SAMPLING PROGRAM HAS BEEN UNDER REVIEW BY THE THREE AGENCIES INVOLVED. PLANS FOR UPDATING AND MODIFYING THE SAMPLING SCHEDULE WILL BE COMPLETED SHORTLY AND MADE READY FOR IMPLEMENTATION BY 1 NOV. THE REVIEW CONSISTS OF VALIDATING ALL OF THE DATA COLLECTED FROM PREVIOUSLY SAMPLED SITES, DELETION OF REDUNDANT SITES, ADDITION OF NEW SITES, AND REPAIR OF WELLS THAT WILL CONTINUE TO BE MONITORED. ALL FUTURE SAMPLING WILL BE CONDUCTED ON A QUARTERLY BASIS, STAGGERED TO DISTRIBUTE THE WORK LOAD EVENLY OVER EACH QUARTER.

THE REVISED PLAN WILL INCORPORATE AS MANY SAMPLE SITES ON A QUARTERLY BASIS, AVERAGING 10 TO 15 SITES PER WEEK. OFF-POST WATER COLLECTION WILL BE CONDUCTED BY TRI-COUNTY HEALTH PERSONNEL AND TRANSMITTED TO RMA FOR ANALYSES.

MANY SITES CURRENTLY BEING SAMPLED WILL BE DELETED FROM THE NEW PLAN, WHILE OTHER SITES WILL BE ADDED IN ORDER TO OBTAIN BETTER REPRESENTATION AND ACHIEVE MORE UNIFORM GEOGRAPHIC DISTRIBUTION OF THE SAMPLING SITES. THE RETAINED SITES WILL REQUIRE VARIOUS LEVELS OF WELL-CASING REPAIR. IT IS ANTICIPATED THAT 10 TO 20 PERCENT OF THE PRESENT WELL INSTALLATIONS WILL REQUIRE REPLACEMENT. NEARLY ALL WELLS WILL REQUIRE SOME FORM OF CASING REPAIR TO PROVIDE A CONSISTENT DATUM AT EACH WELL FOR ACCURATE WATER-LEVEL MEASUREMENTS.

SEVERAL WELLS, PRESENTLY BEING SAMPLED, HAVE MULTIPLE SCREENS PER WELL. THIS LIMITS THE INTERPRETATION OF THE DATA FOR THESE LOCATIONS. IN ORDER TO ACHIEVE STANDARDIZATION OF WATER COLLECTION METHODS, THESE WELLS WILL REQUIRE REPLACEMENT. THIS REPAIR IS NECESSARY TO ACHIEVE MULTIPLE USAGE; THAT IS, IN ADDITION TO GATHERING CHEMICAL DATA. THE WELLS WILL BE USED FOR GROUNDWATER-TABLE MONITORING IN AN EFFORT TO INTERPRET THE RMA GROUNDWATER FLOW SYSTEM AND ALSO MONITOR THE EFFECTIVENESS OF THE INTERIM CONTAINMENT SYSTEM.

ALL SITES CURRENTLY BEING SAMPLED NEED TO BE ACCURATELY SURVEYED TO DETERMINE BOTH A REFERENCE ELEVATION AND THE

GEOGRAPHICAL GRID LOCATIONS. THE WELLS WILL BE INCORPORATED INTO THE STATE PLANE COORDINATE SYSTEM. ALSO, IN ORDER TO EVALUATE POTENTIAL ENERGY GRADIENTS IN THE GROUNDWATER FLOW SYSTEM, ACCURATE VERTICAL CONTROL IS NECESSARY FOR MAKING PRECISE WATER TABLE ELEVATION MEASUREMENTS.

THE RESULTS OF THE 360 PROGRAM WILL BE REVIEWED ON A QUARTERLY BASIS, WHICH WILL BE ONE MONTH FOLLOWING THE QUARTERLY SAMPLING SCHEDULE. THIS WILL ALLOW SUFFICIENT TIME FOR COLLECTION AND ANALYSES OF THE DATA COLLECTED DURING THE PREVIOUS QUARTER. DURING THE REVIEW, THE NEED FOR ADDITION OR DELETION OF SAMPLING SITES WILL BE DETERMINED.

MANPOWER REQUIREMENTS - THE WORK LOAD REQUIREMENTS FOR WATER SURVEILLANCE CONSISTS OF SAMPLING OF SITES ON A QUARTERLY BASIS, WATER-LEVEL DETERMINATIONS ON A MONTHLY BASIS, AND CONTINUOUS WELL RECORDER MAINTENANCE. THIS EFFORT WILL REQUIRE, ON THE AVERAGE, THREE MANDAYS PER WEEK.

2. GEOPHYSICAL SAMPLING - THE MAJOR OBJECTIVE OF GEOPHYSICAL STUDIES IN FY 77 IS FOCUSED TOWARD THE NORTH BOUNDARY

VIEW GRAPH 14

CONTAINMENT SYSTEMS. A DRILLING PROGRAM HAS BEEN ACTIVE TO PROVIDE THE NECESSARY STRATIGRAPHIC AND HYDROLOGICAL INFORMATION IN SECTIONS 23 AND 24. GROUNDWATER MONITORING WELLS ARE ALSO BEING INSTALLED.

ALL OF THE INFORMATION GATHERED FROM THIS PRELIMINARY EXPLORATION STUDY IS INPUTED INTO RATIONAL MANAGERIAL-DECISION MAKING IN THE DESIGN AND SELECTION OF AN INTERIM NORTHERN BOUNDARY CONTAINMENT SYSTEM.

IT IS ANTICIPATED THAT AFTER THE EMPLACEMENT OF THE CONTAINMENT/TREATMENT SYSTEM (ABOUT 1 JUL), CONTINUED MONITORING OF THE DEWATERING/RECHARGE SYSTEM WILL BE REQUIRED.

VIEW GRAPH 15

ADDITIONAL SUBSURFACE INVESTIGATIONS ALONG THE NORTH-WEST AND WEST BOUNDARY (IRONDALE-DUPONT LINE) WILL BE REQUIRED. IN THIS AREA, INVESTIGATIONS WILL CONSIST OF TWO OPERATION PHASES. THE RECONNAISSANCE GEOPHYSICAL PHASE INVOLVES CONTRACTOR SUPPORT, PRINCIPALLY FOR SEISMIC AND RESISTIVITY STUDIES. THIS PROVIDES RAPID ACQUISITION OF CONTINUOUS DATA ON BEDROCK AND WATER TABLE DEPTHS THAT IS NECESSARY TO SUPPORT DRILLING OPERATIONS. OTHER GEOPHYSICAL TECHNIQUES MAY ALSO BE EMPLOYED, SUCH AS MAGNETOMETER, SOIL-GAS, AND DOWN HOLE GEOPHYSICAL LOGGING STUDIES.

THE VERIFICATION WILL NECESSARILY OVERLAP WITH THE GEOPHYSICAL PHASE. THIS ASPECT INCLUDES DRILLING OF TEST HOLES FOR: (1) STRATIGRAPHIC DETERMINATION; (2) COLLECTION OF SOIL SAMPLES FOR LABORATORY ANALYSES TO VERIFY AND CALIBRATE THE GEOPHYSICAL STUDIES; AND (3) COLLECTION OF WATER SAMPLES FOR GROUNDWATER CONTAMINATION CHARACTERIZATION.

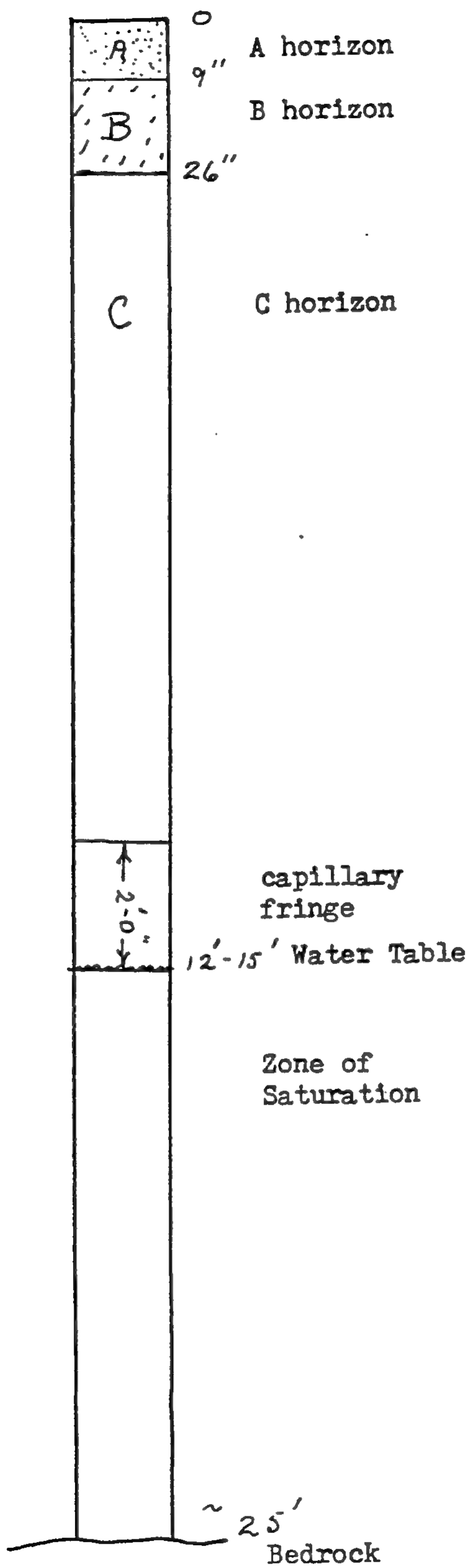
AS PART OF THE OVERALL PROGRAM TO EVALUATE THE TOTAL RMA GROUNDWATER FLOW SYSTEM, EXPLORATORY WELLS WILL BE DRILLED AND INSTALLED AT SELECTED SITES. THESE WELLS WILL BE USED FOR WATER-TABLE MEASUREMENTS, AS WELL AS GROUNDWATER CHEMICAL ANALYSES. SOME OF THESE WELLS WILL SERVE DUAL PURPOSES, AND LOCATION WILL BE IN PART DETERMINED BY THEIR UTILITY IN THE 360° WATER-MONITORING PROGRAM AND WILL BE INCORPORATED INTO THE OVERALL DESIGN.

THE MAIN OBJECTIVE OF THE IR MISSION AT RMA IS IDENTIFICATION OF THE CONTAMINANT SOURCES, INCLUDING KNOWN MAJOR

VIEW GRAPH 16

SOURCES SUCH AS BASINS A AND F. THESE AREAS ARE KNOWN TO BE CONTRIBUTING TO CONTAMINANT MIGRATION; HOWEVER, VERY LITTLE IS KNOWN CONCERNING THE QUANTITIES, VELOCITIES, PATHWAYS, AND MECHANISMS OF CONTAMINANT BEHAVIOR. PRELIMINARY EXPLORATORY GEOPHYSICAL WORK WILL BE NEEDED TO CHARACTERIZE BOTH STRATIGRAPHY AND GEOHYDROLOGY TO SUPPORT PLANNING FUTURE CLEANUP PROCEEDINGS.

TYPICAL R.M.A.
SOIL PROFILE



SAMPLING SCHEME FOR
TYPICAL BORING

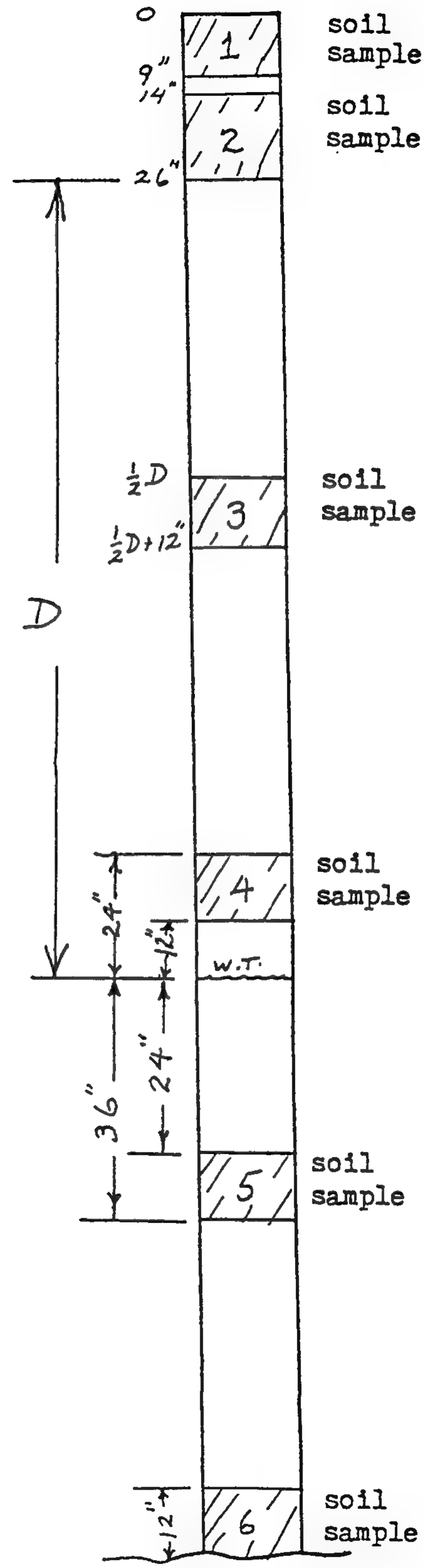
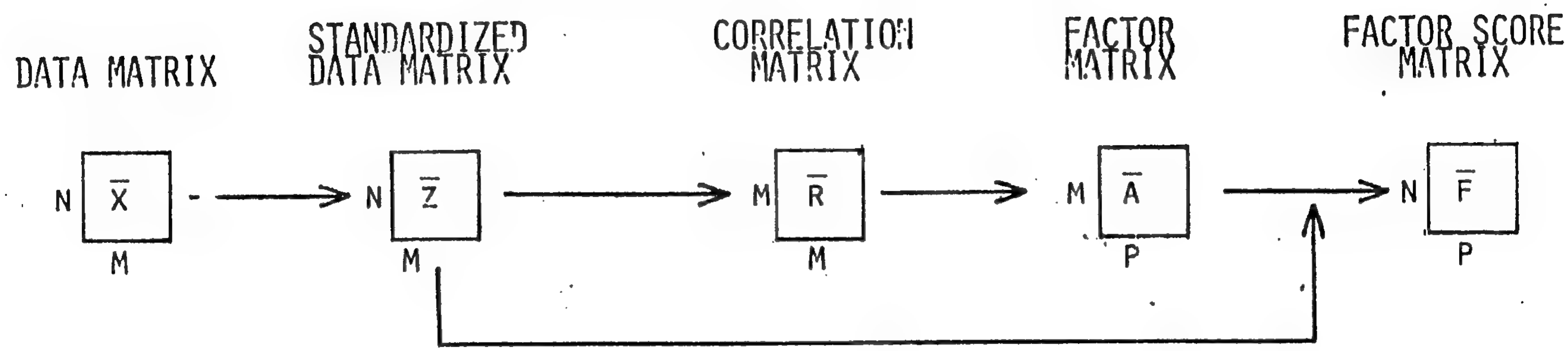


Figure 16

FLOW DIAGRAM OF PRINCIPAL
COMPONENTS ANALYSIS OF A DATA MATRIX



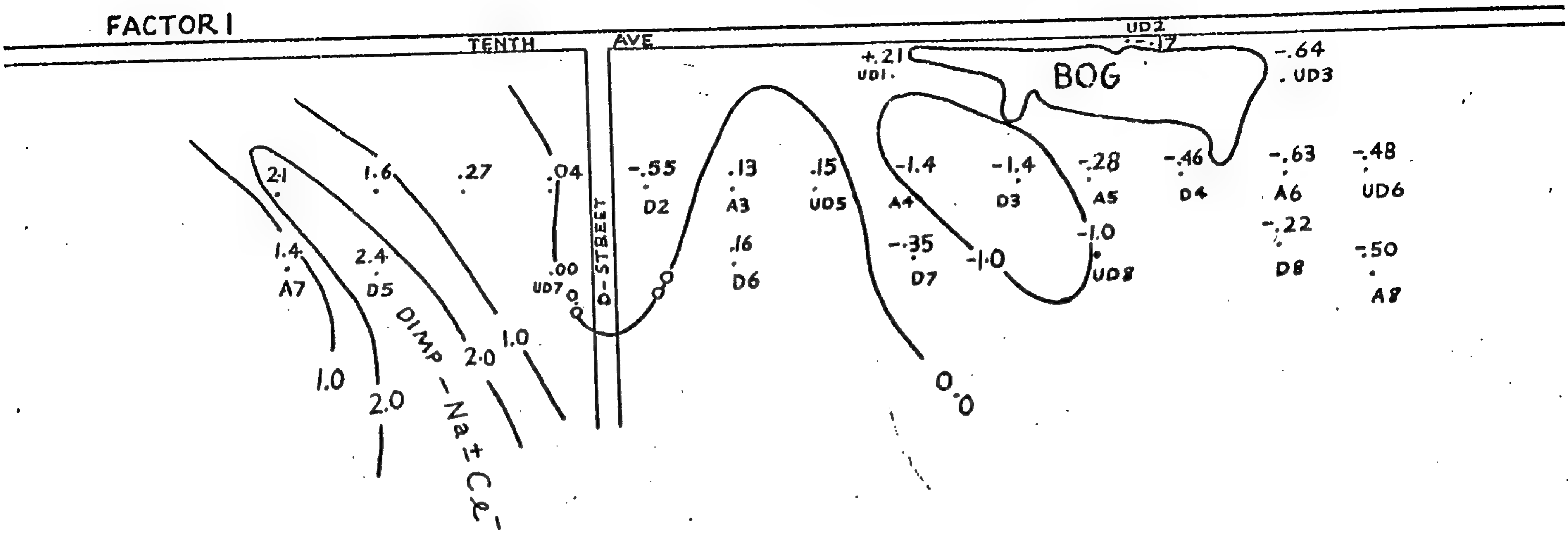
ROTATED FACTOR MATRIX

	VARIABLE	FACTOR 1	FACTOR 2	FACTOR 3
Cl	1	.95432	.05771	.11978
Na	2	.86626	- .32869	- .04775
$SO_4^=$	3	.07578	- .93095	- .09502
NO_2/NO_3	4	- .36283	- .86278	- .10680
HARDNESS	5	.42726	- .87938	- .00878
pH	6	- .59616	.32518	- .52109
DIMP	7	.93632	.23634	- .12260
DCPD	8	.02320	.31009	.89032

FACTOR SCORES

	Case	Factor 1	Factor 2	Factor 3
A-1	1	1.63071	.14408	- .63347
A-2	2	.04633	.92987	- .24377
A-3	3	.13449	.57079	3.43871
A-4	4	- 1.46349	1.25532	- .37236
A-5	5	- .28705	- .26986	.07464
A-6	6	- .63546	- 1.16170	- .26449
A-7	7	1.47940	- .57263	.13603
A-8	8	- .50271	- 1.52047	- .57213
D-1	9	.27072	.78231	- .12060
D-2	10	- .55679	1.02852	- .26528
D-3	11	- 1.44698	1.19991	- .75781
D-4	12	- .46282	- 1.09225	.01025
D-5	13	2.46890	.09476	- .85149
D-6	14	.16364	.59346	2.25481
D-7	15	- .35982	.69941	- .03682
D-8	16	- .22932	- 1.60303	.04838
UD-1	17	- .21799	.51007	.64720
UD-2	18	- .17469	.23713	- .05952
UD-4	19	2.12827	.10989	- .45420
UD-5	20	.15308	.39788	- .23061
UD-6	21	- .48184	- 2.18231	.18710
UD-7	22	.00252	1.04124	- .93460
UD-8	23	- 1.01234	.24606	-1.39069
UD-3	24	- .64515	- 1.44025	.39619

FACTOR 1



FACTOR 3

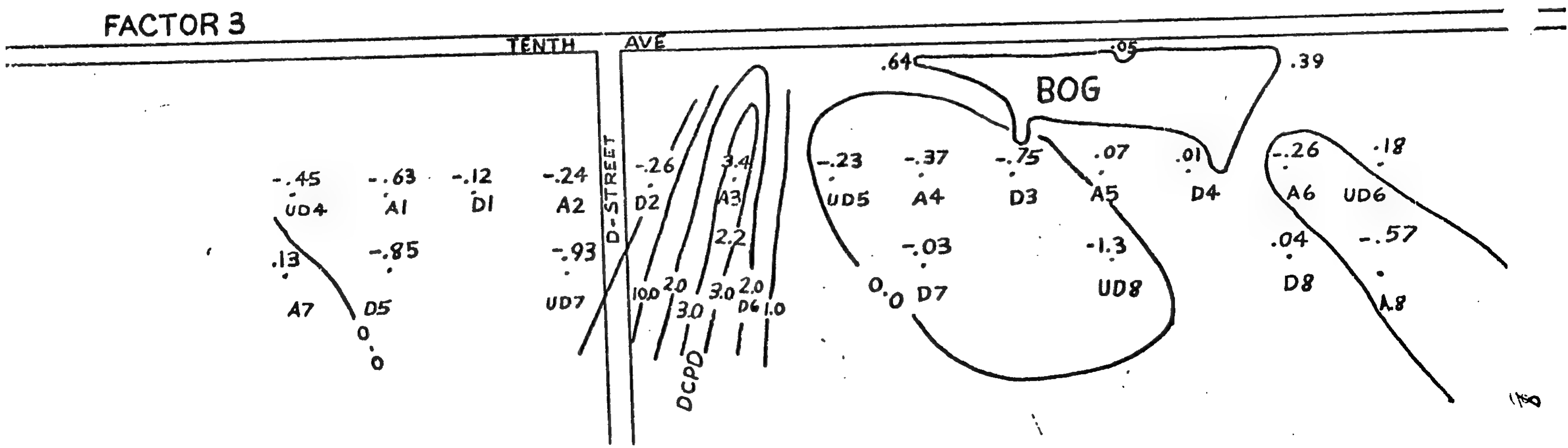
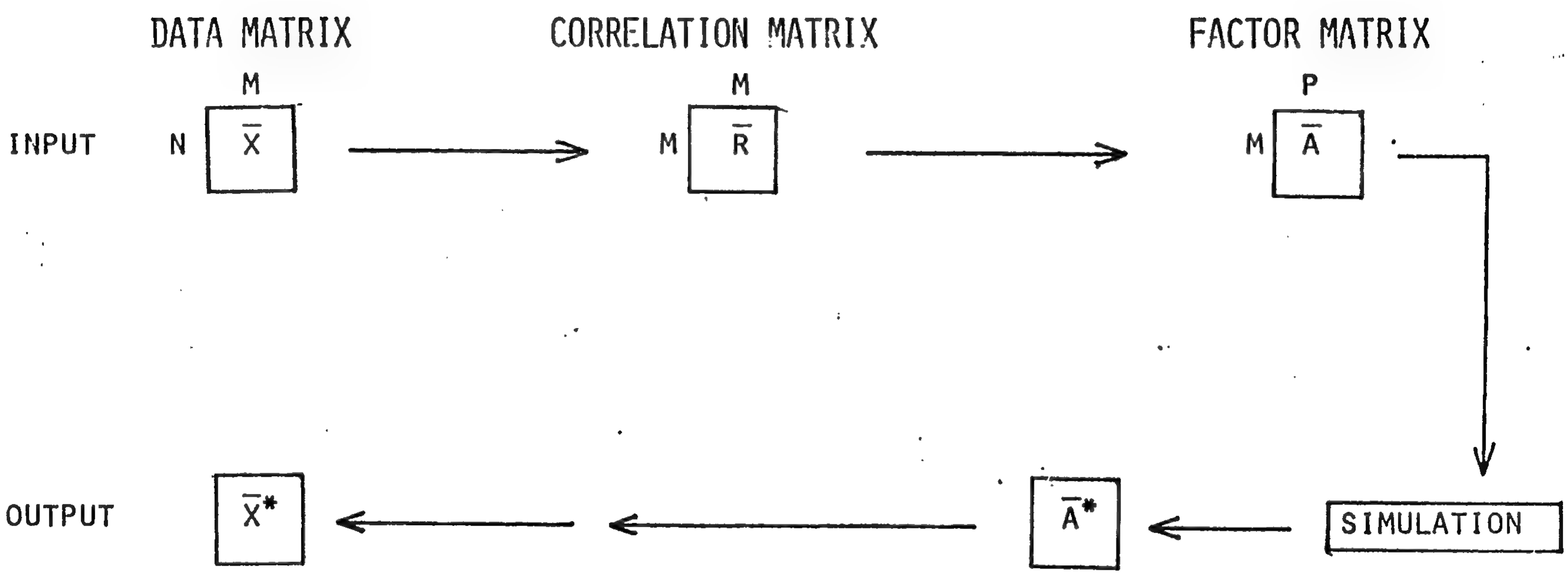


TABLE 3

CORRELATION MATRIX

	1 Cl^-	2 NA	3 $SO_4^=$	4 NO_2/NO_3	5 HRDNS	6 pH	7 DIMP	8 DCPD
1	1.00000							
2	.76139	1.00000						
3	.03735	.33400	1.00000					
4	-.39784	.01110	.72653	1.00000				
5	.36324	.66785	.83121	.59162	1.00000			
6	-.55539	-.50381	-.25455	.04583	-.50311	1.00000		
7	.89145	.72437	-.12501	-.48784	.17548	-.39476	1.00000	
8	.17279	-.05811	-.34515	-.32579	-.25761	-.20842	.01198	1.00000

FLOW DIAGRAM OF FACTORIAL SIMULATION



M-VARIABLES
P-FACTORS
N-SAMPLES

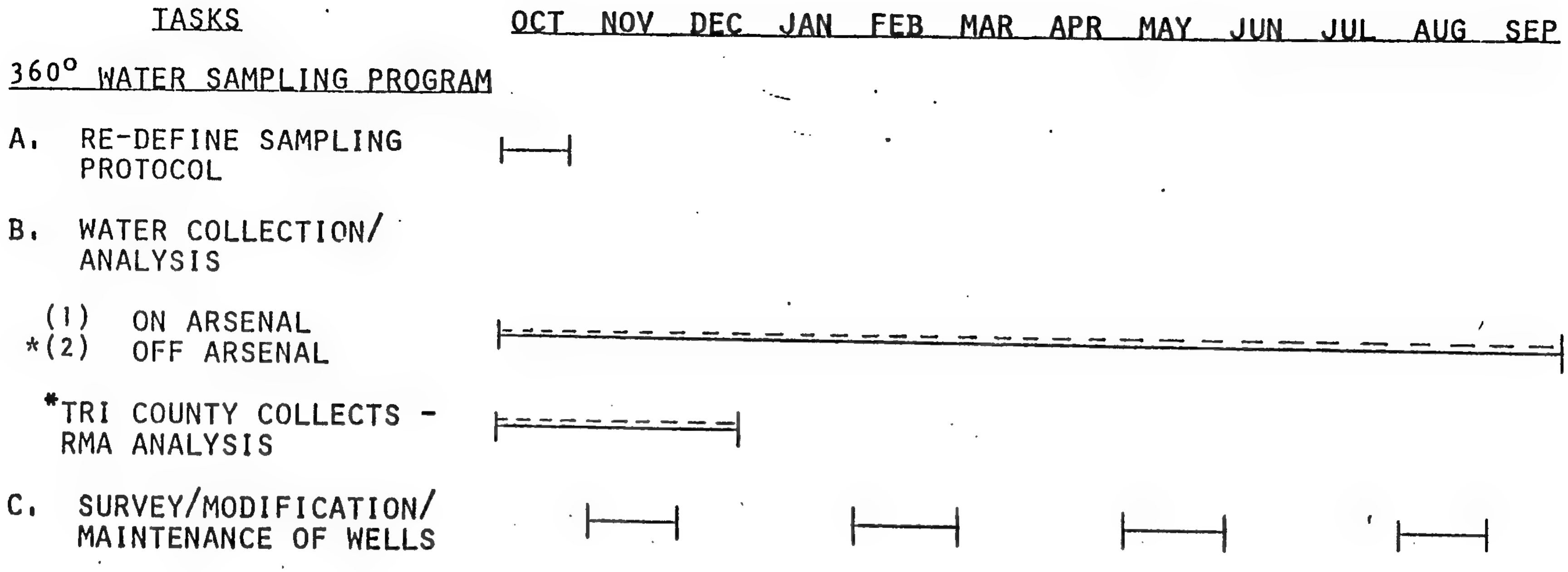
*THESE MATRICES ARE SIMULATED.

SAMPLING PROGRAM

I. 360^{o} SURFACE AND GROUNDWATER SAMPLING

II. GEOPHYSICAL EXPLORATORY SAMPLING

III. COMPREHENSIVE SOIL AND GROUNDWATER SAMPLING


TASKS
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
360° WATER SAMPLING PROGRAM
A. RE-DEFINE SAMPLING PROTOCOL
B. WATER COLLECTION/ ANALYSIS
(1) ON ARSENAL
*(2) OFF ARSENAL
*TRI COUNTY COLLECTS - RMA ANALYSIS
C. SURVEY/MODIFICATION/ MAINTENANCE OF WELLS

TASKS

GEO-PHYSICAL

A. NORTH BOUNDARY

(1) COMPLETE SUPPORT FOR INTERIM CONTAINMENT SYSTEM

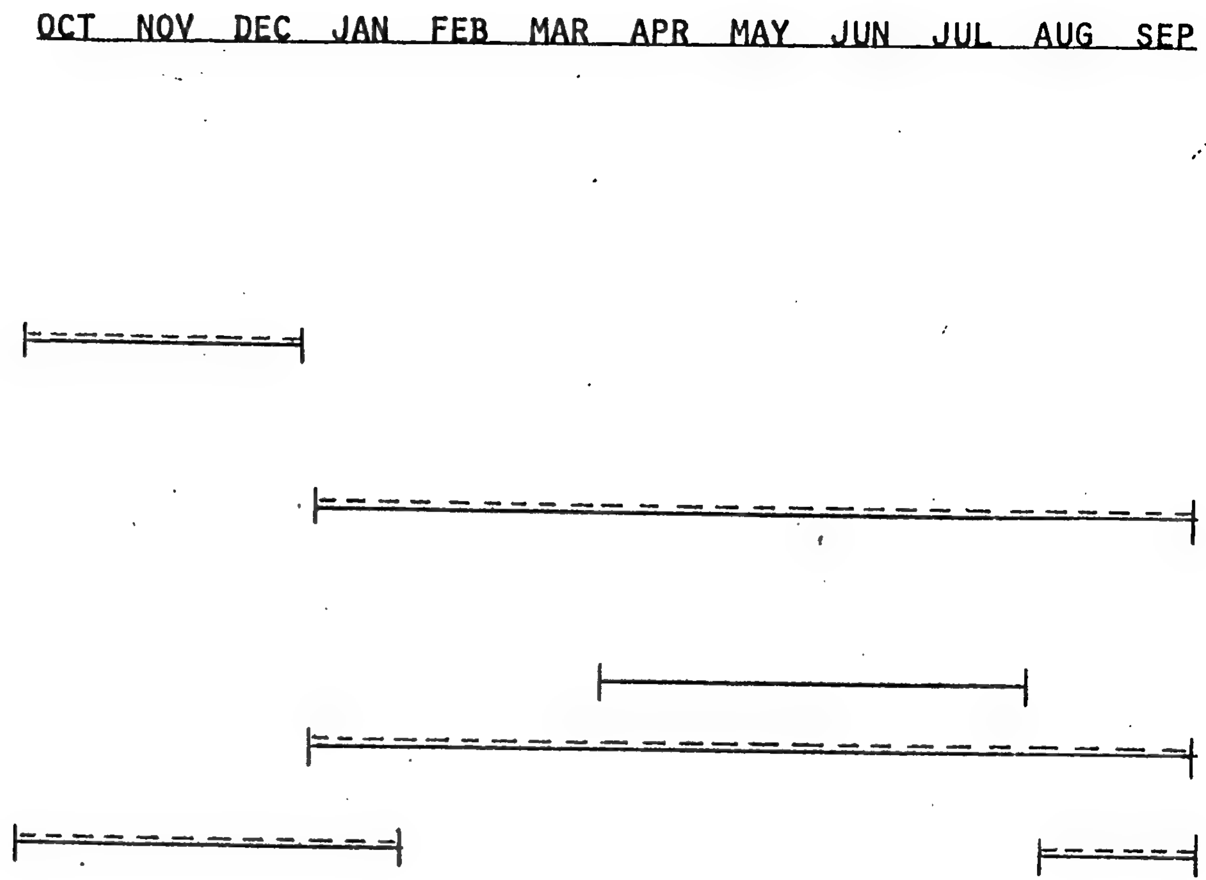
(A) PUMPING TESTS; PIEZOMETER INSTALLATION; CONSULTANT SERVICES; SOIL ANALYSIS

(2) MONITORING/ASSESSMENT OF CONTAINMENT SYSTEM (INCLUSIVE WATER TREATMENT) ON GEO. HYDROLOGICAL ENVIRONMENT

(A) CONTAINMENT SYSTEM

(B) TREATMENT SYSTEM (GROUND WATER MONITORING)

(3) USGS MICRO-SCALE COMPUTER SIMULATION



TASKS	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
B. NORTH WEST/WEST BOUNDARY												
(1) IRONDALE/DUPONT LINE												
(A) GEO-PHYSICAL INVESTIGATIONS (CONTRACTOR) & EVALUATION												

TASKS — OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP

(B) DRILLING; STRATIGRAPHIC;
& HYDROLOGICAL CHARACTERIZATION

(1) CORING

(2) LAB ANALYSIS

(3) SURVEYING SUPPORT

TASKS

COMPREHENSIVE SURVEY (WATER/SOILS)

A. INTERIM FACILITY STORAGE/ OPERATIONS

B. PROCURE SUPPLIES/EQUIP. (INTERIM OPERATIONS)

C. DEVELOP COLLECTION PROCEDURES SAMPLING

D. B-741 FACILITY OPERATIONAL

E. INITIATE PILOT SOIL/WATER SAMPLING PROGRAM

(1) FIELD DRILL OPERATIONS

(2) FIELD VARIABLE CHARACTERIZATION

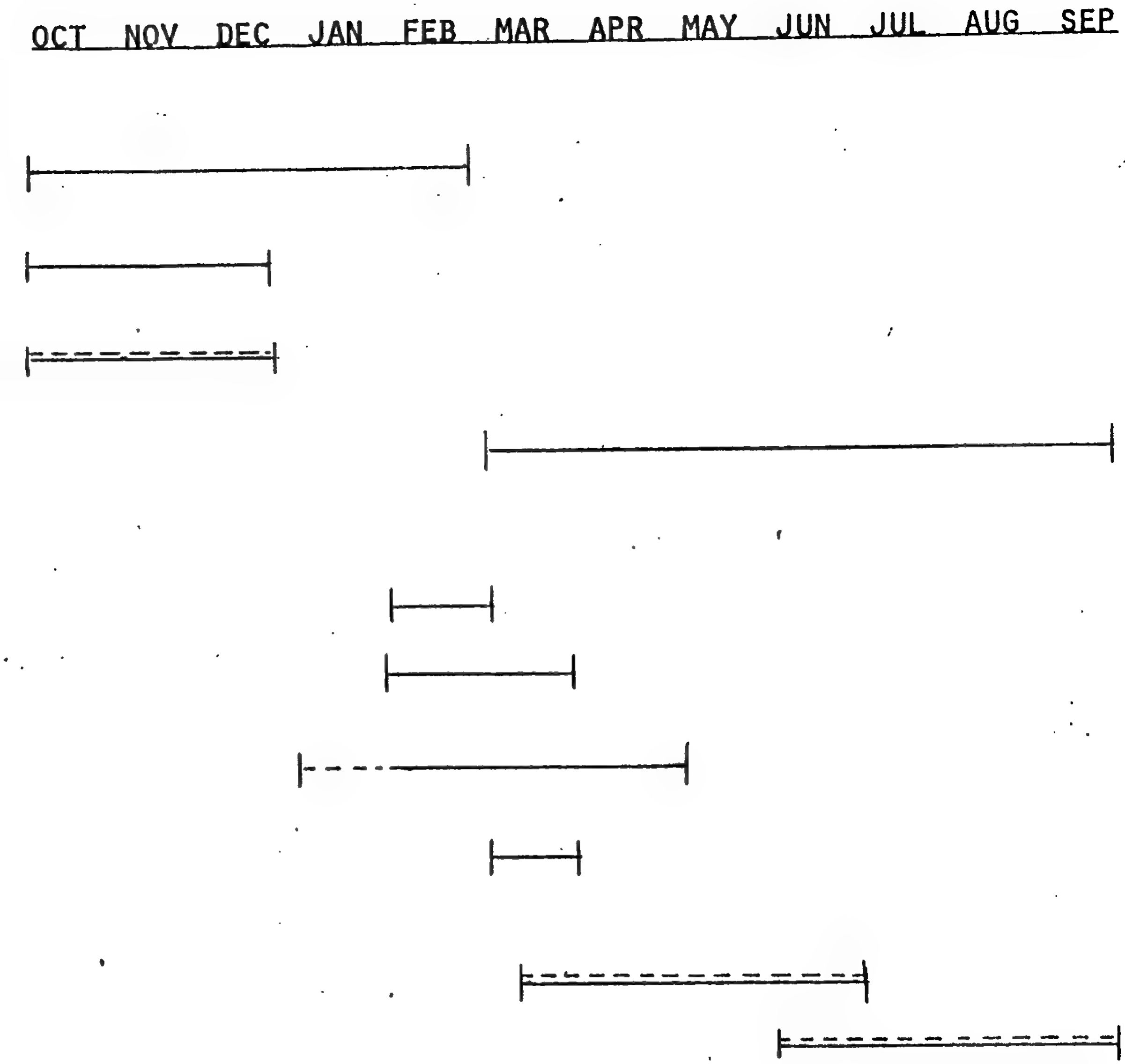
(3) LAB VARIABLE CHARACTERIZATION

(4) DATA REVIEW & ANALYSIS

F. SOIL/WATER

(1) SAMPLING PLAN UP-DATE

(2) IMPLEMENTATION OF FULL SCALE PLAN



TASKS	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
G. MODEL DESIGN/CONSTRUCTION												
(1) PRELIMINARY DATA PURIFICATION												
(2) DATA PURIFICATION AND MODEL DESIGN/TESTING												

MANPOWER NEEDS - THE GEOPHYSICAL INVESTIGATIONS WILL BE PERFORMED BY A CONTRACTOR AND PARTIALLY SUPPORTED BY RMA STAFF. ADDITIONAL LABORATORY ANALYSES OF SOILS TO BE PERFORMED UNDER THIS TASK WILL GREATLY INCREASE THE WORK REQUIREMENTS OF THE SOILS LABORATORY, REQUIRING AN ADDITIONAL TWO TO THREE MANDAYS PER WEEK. THE DRILLING OPERATIONS WILL REQUIRE A TECHNICIAN TO LOG THE TEST HOLES, COLLECT THE SAMPLES, AND PREPARE THESE SAMPLES FOR LABORATORY ANALYSES. THE FIELD INVESTIGATIONS TO BE PERFORMED UNDER THIS TASK ARE INTERMITTENT OVER FY 77. IT IS ANTICIPATED THAT AN AVERAGE OF 10 MANDAYS OF TECHNICAL HELP PER WEEK WOULD BE REQUIRED BEGINNING 1 JAN.

VIEW GRAPH 17

3. THE COMPREHENSIVE SURVEY OF SOILS AND GROUNDWATER TO IDENTIFY AND MAP THE DEGREE OF CONTAMINATION AT RMA CONSISTS OF GATHERING DATA FROM SAMPLE DRILL SITES PATTERNED TO INTERCEPT THE MAJOR AREAS OF CONTAMINATION. FOUR CATEGORIES OF DATA WILL BE GATHERED AT EACH SAMPLING BORE HOLE. THESE ARE: (1) FIELD MEASUREMENTS OF GEOGRAPHIC LOCATIONS OF THE SAMPLING SITE, SURFACE MORPHOLOGY, PHYSICAL PROPERTIES OF SOILS, GROUNDWATER LEVELS, AND BEDROCK; (2) LABORATORY ANALYSIS OF THE MECHANICAL PROPERTIES OF SOILS; (3) LABORATORY ANALYSIS OF THE CHEMICAL PROPERTIES OF SOILS AND GROUNDWATER; AND (4) FIELD MEASUREMENTS ON MICRO-ECOLOGY SUCH AS VEGETATION AND INVERTEBRATES.

THE COMPREHENSIVE SURVEY WILL BE DIVIDED INTO TWO TIME PHASES: (1) PILOT PHASE AND (2) SURVEY IMPLEMENTATION PHASE. THE PILOT PHASE EXTENDS FROM 1 OCT TO 1 MAR. THIS TIME FRAME COINCIDES WITH THE TIME PERIOD DURING WHICH THE PERMANENT LABORATORY FACILITIES WILL BE IN PREPARATION AND THEREFORE WILL NOT BE AVAILABLE FOR USE. DURING THIS PHASE, PROCEDURES FOR SAMPLING OF SOILS AND GROUNDWATER AND THE COLLECTION AND ANALYSES OF DATA WILL BE VERIFIED AND FIELD TESTED. THE IMPLEMENTATION OF THE COMPREHENSIVE SURVEY WILL COINCIDE WITH THE AVAILABILITY OF A FULL-SCALE SOILS LABORATORY FACILITY (BUILDING 741).

THE INITIAL EFFORT IN THE PILOT PHASE IS DIRECTED TOWARD THE IDENTIFICATION AND ACQUISITION OF NECESSARY LABORATORY EQUIPMENT.

BOTH THE OBJECTIVES OF THE COMPREHENSIVE SURVEY AND THE FIELD PROCEDURES TO BE USED IN COLLECTING AND DESCRIBING THE PHYSICAL PROPERTIES OF THE SAMPLES HAVE BEEN DEVELOPED. STANDARD LABORATORY PROCEDURES IN PERFORMING SOIL ANALYSIS ARE BEING EVALUATED FOR THEIR APPLICABILITY TO THE RMA SOILS. THE PROCEDURES TO BE FOLLOWED WILL BE IDENTIFIED

AND READY FOR IMPLEMENTATION BY 1 JAN. DURING THE INITIAL PILOT PHASE, AN INTERIM SOIL LABORATORY FACILITY WILL BE USED FOR SAMPLE STORAGE AND TEST OPERATIONS.

SOIL AND WATER COLLECTION AND STORAGE PROCEDURES WILL BE FIELD TESTED BETWEEN 1 JAN AND 1 MAR, BY WHICH TIME THE SOILS LABORATORY FACILITY IS SCHEDULED FOR COMPLETION. THE PILOT-SCALE TESTING PHASE WILL INCLUDE BOTH FIELD OPERATIONS AND PRELIMINARY LABORATORY ANALYSES.

NORMAL FIELD WORK WILL CONSIST OF AN INITIAL SURVEY OF THE SITE BY THE ECOSYSTEMS GROUP, FOLLOWED BY A DRILLING AND SAMPLING OPERATION. LIMITED LABORATORY TESTS WILL BE PERFORMED DEPENDING ON THE INTERIM FACILITY AVAILABLE. HOWEVER, THEY WILL INCLUDE KEY SOIL CHEMICAL AND MECHANICAL DETERMINATIONS. SEVERAL WELLS WILL BE CASED FOR LONG-TERM GROUNDWATER FLOW DETERMINATIONS.

WHEN LABORATORY FACILITIES BECOME OPERATIONAL, DATA GATHERED DURING THE PILOT PHASE WILL BE REVIEWED, ALONG WITH THE TEST PROCEDURES USED. THE DETAILED PLAN WILL BE UPDATED AND MODIFIED AS NECESSARY, AND AN INITIAL START UP OF THE SURVEY IMPLEMENTATION PHASE WILL BEGIN 1 APR. THE "SHAKEDOWN" OF PROCEDURES WILL TAKE BETWEEN 60 AND 90 DAYS.

VIEW GRAPH 19

AS DATA BECOMES AVAILABLE, HYPOTHESIS ON THE BEHAVIOR OF THE ENVIRONMENT AND CONTAMINANT MIGRATION WILL BE FORMULATED AND TESTED. THIS INFORMATION WILL BE INCORPORATED INTO A MODEL DESIGN AND TESTING FUNCTION. AS THE PROGRAM CONTINUES THROUGH FY 77, THE MODELING EFFORT WILL BECOME A SIGNIFICANT PART OF THE COMPREHENSIVE SURVEY.

MANPOWER NEEDS - BOTH THE PILOT PHASE AND THE OPERATIONAL COMPREHENSIVE SURVEY WILL REQUIRE MANPOWER SUPPORT. THE MANPOWER IDENTIFIED IN THE 360^{o} PROGRAM AND GEOPHYSICAL TASK WILL BE INTEGRATED WITH THE MANPOWER NEEDS FOR THE COMPREHENSIVE SURVEY. THE TWO TECHNICIANS IDENTIFIED WILL BE USED TO SUPPORT THE PILOT PHASE OF THIS TASK. BY THE BEGINNING OF THE PROGRAM OPERATIONAL PHASE, ADDITIONAL MANPOWER WILL BE NEEDED TO KEEP UP WITH THE INCREASED WORK LOAD PLACED ON THE SOIL LABORATORY OPERATION.

THE COMPREHENSIVE SURVEY WILL REQUIRE SEVEN TO EIGHT MANDAYS PER WEEK FOR TECHNICIAN SUPPORT. THE PROGRAM PHASE WILL REQUIRE ONE ADDITIONAL SOIL SCIENTIST.

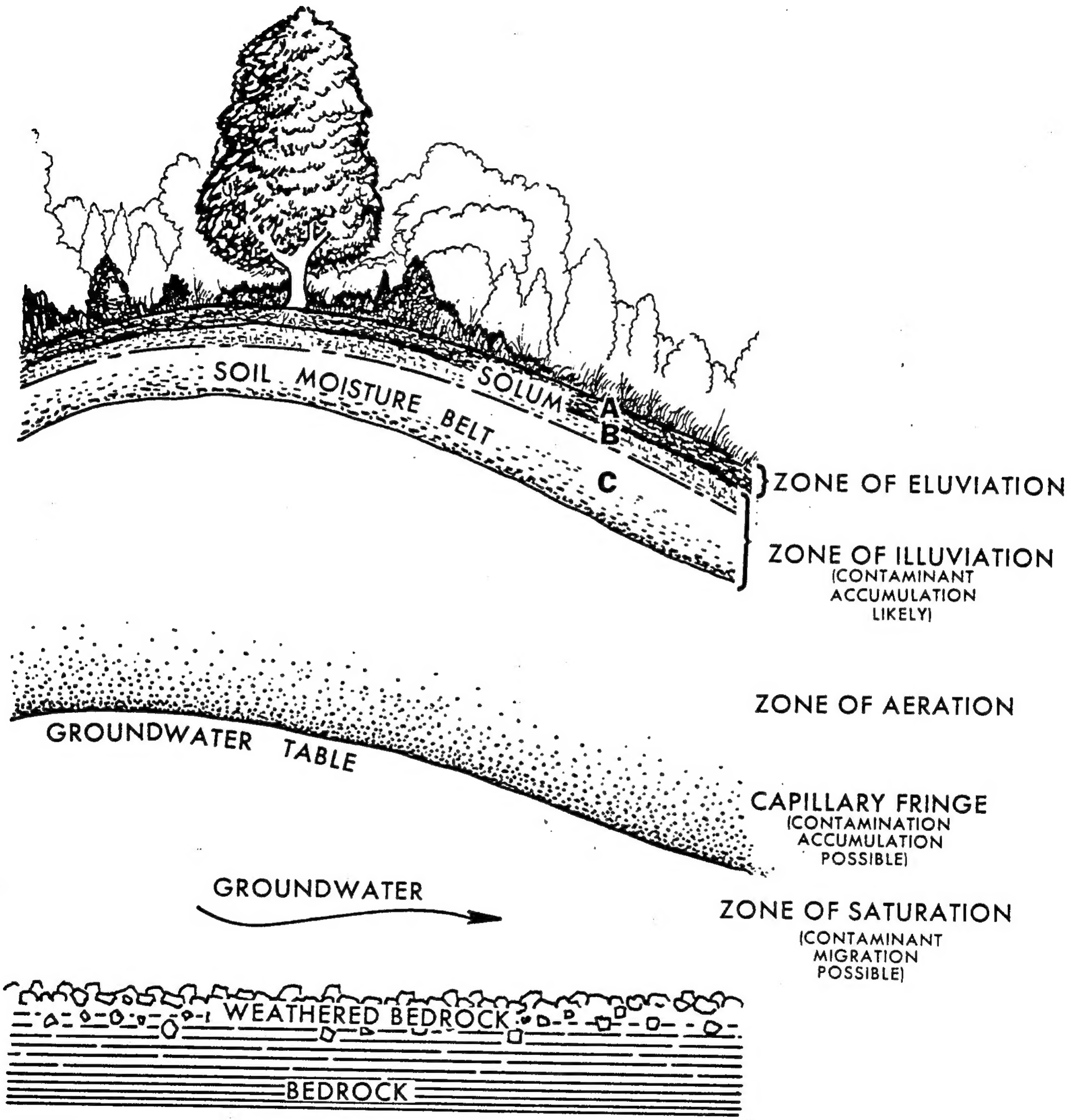
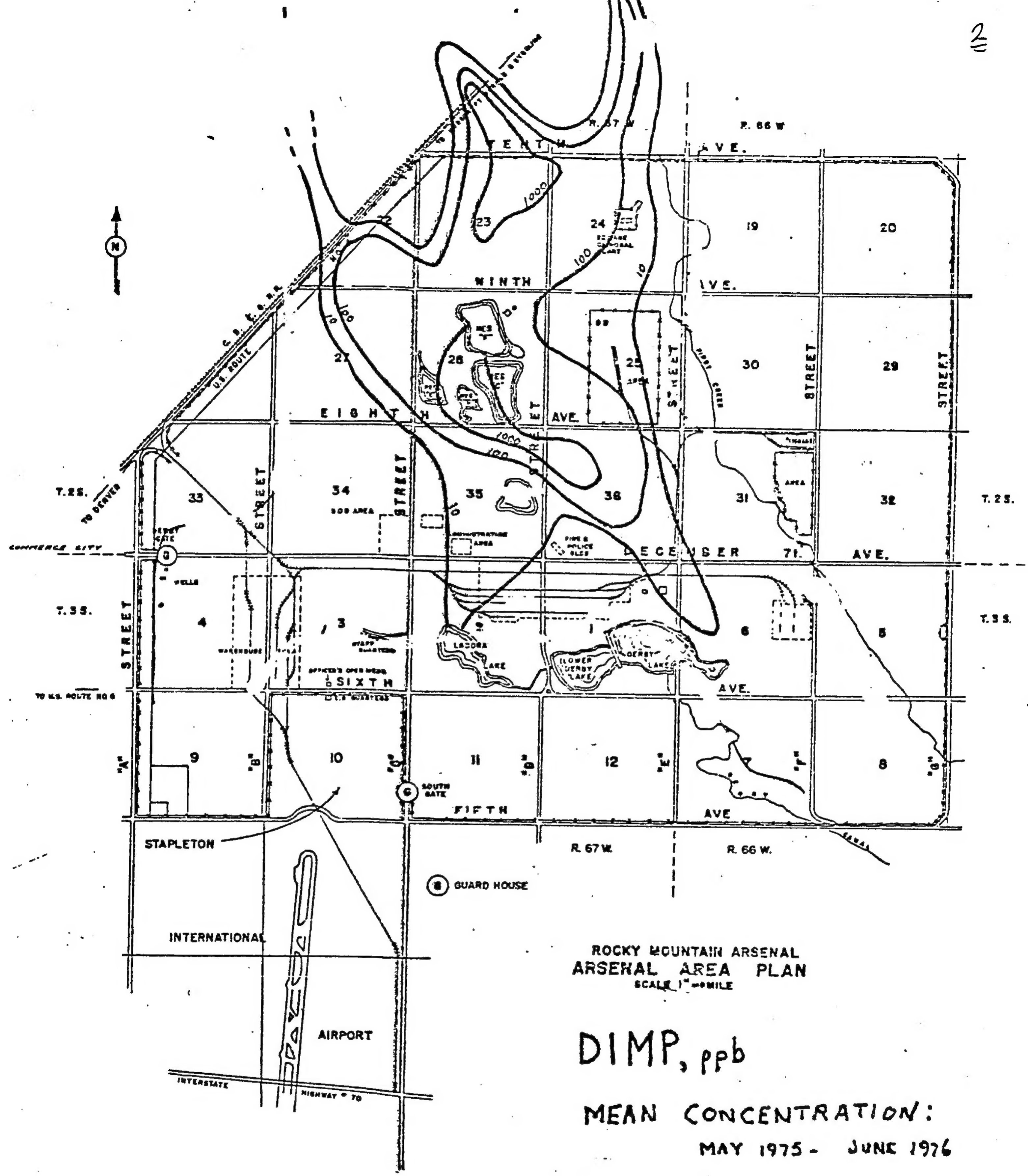


Figure 2. CROSS-SECTION OF UNCONSOLIDATED MANTLE

2



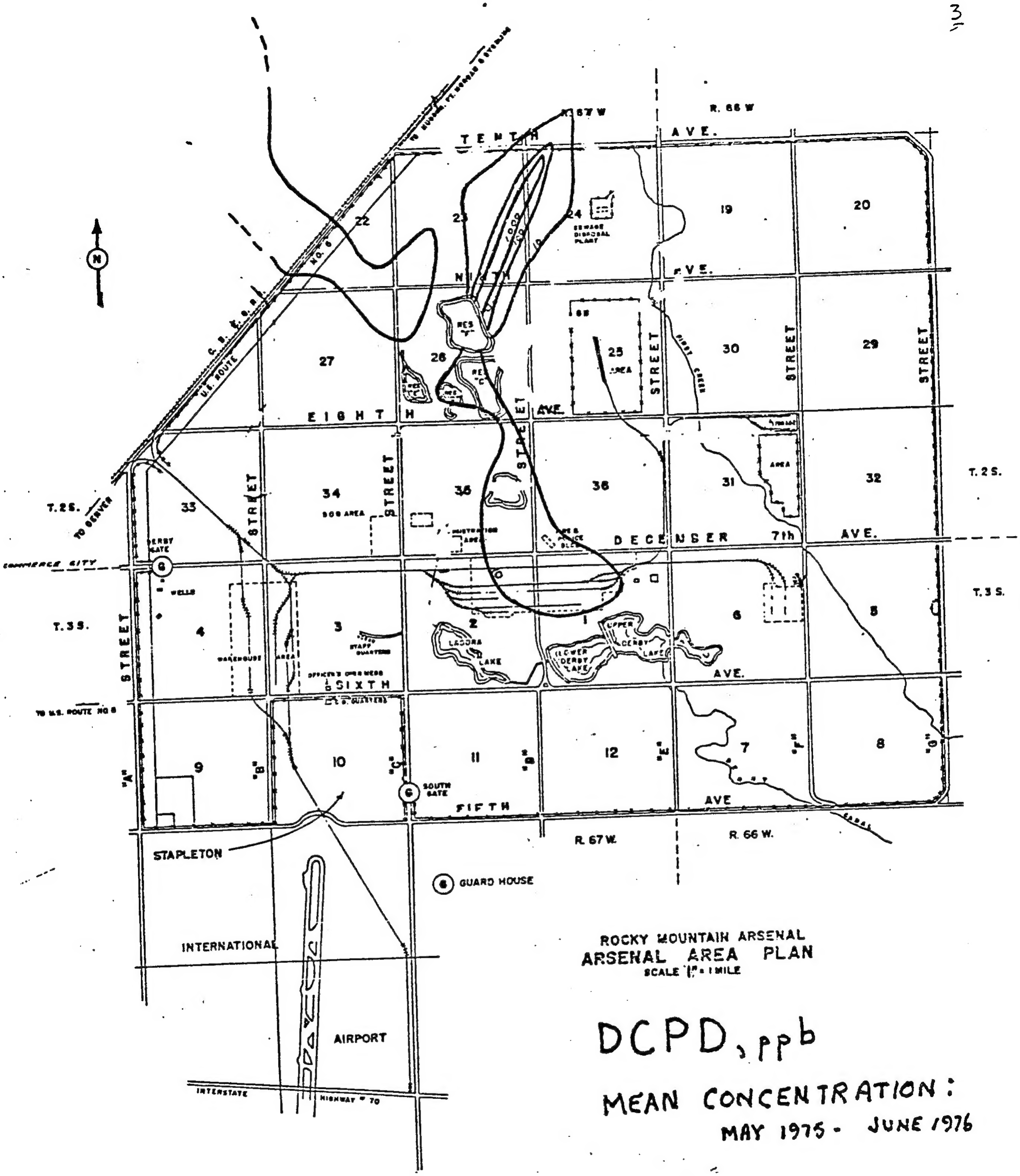
ROCKY MOUNTAIN ARSENAL
ARSENAL AREA PLAN
SCALE 1" = MILE

DIMP, ppb

MEAN CONCENTRATION:
MAY 1975 - JUNE 1976

- 1.0 - 10.0
- 10.1 - 100.0
- 100.1 - 1000.0
- >1000

MLD

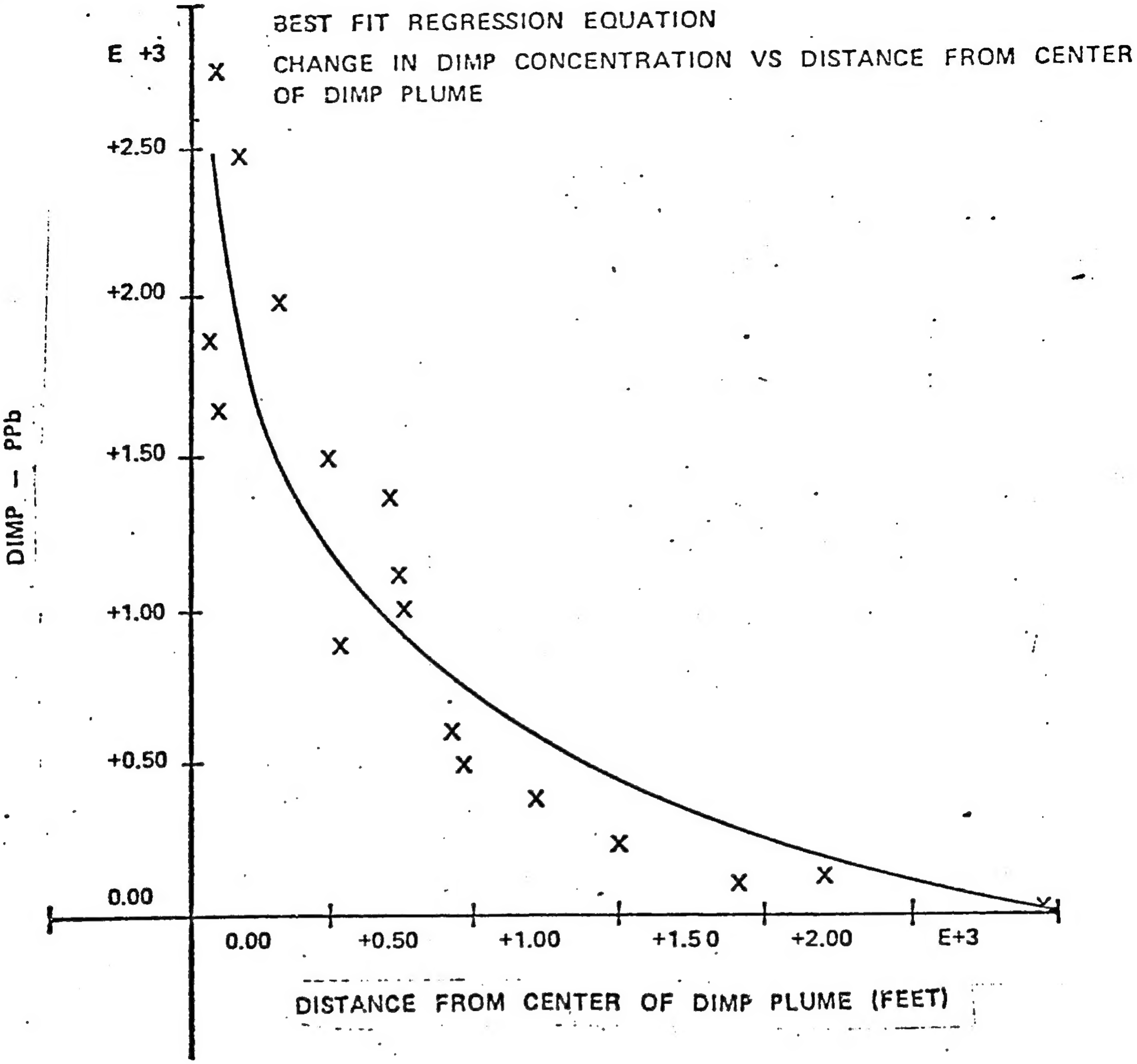


DCPD, ppb

MEAN CONCENTRATION:
MAY 1975 - JUNE 1976

☐ 1.0 – 10.0
☐ 10.1 – 100.0
☐ 100.1 – 1000
☐ >1000

MLD



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A = 5237.70561151
B = −654.921197714
R-SQUARE = 0.811366280354
RES ERROR
145731.828112
MAX(ABS(RESIDUAL))
651.29042082

DIMP CONCENTRATIONS IN RELATION TO CENTER OF PLUME